United States Patent [19]

Seo et al.

[11] **4,114,054**

[45] **Sep. 12, 1978**

[54] **COUPLING CIRCUIT USING A PHOTOCOUPLER**

[75] Inventors: **Mamoru Seo; Akio Uenishi,** both of Itami, Japan

[73] Assignee: **Mitsubishi Denki Kabushiki Kaisha,** Tokyo, Japan

[21] Appl. No.: **764,177**

[22] Filed: **Jan. 31, 1977**

[30] **Foreign Application Priority Data**

Jan. 30, 1976 [JP] Japan 51-9011

[51] **Int. Cl.**[2] **H03K 17/00**

[52] **U.S. Cl.** ..... **307/311;** 250/211 J; 361/56; 361/91

[58] **Field of Search** ..... 307/311, 252 UA, 202 A, 307/237; 350/211 J, 578; 361/56, 91

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,436,548	4/1969	Baird et al.	250/211 J
3,535,532	10/1970	Merryman	250/211 J
3,708,672	1/1973	Marinkovic	307/252 UA
3,801,837	4/1974	Pease et al.	307/311
3,812,382	5/1974	Pascente	307/252 UA
3,816,763	6/1974	Korn et al.	307/252 UA
3,911,297	10/1975	Mervin et al.	307/311
3,940,634	2/1976	Grogan	307/311
3,958,175	5/1976	Braun	307/311

Primary Examiner—Stanley D. Miller, Jr.
Assistant Examiner—B. P. Davis
Attorney, Agent, or Firm—Oblon, Fisher, Spivak, McClelland & Maier

[57] **ABSTRACT**

A solid state relay is arranged in high density to connect a first circuit comprising an outer signal source to a second circuit for driving a load by a photocoupler. A diode or a capacitor is connected in parallel to the light-receiving element of the photocoupler to maintain the voltage between the terminals of the light-receiving element to less than the reverse breakdown voltage of the light-receiving element when a surge voltage having rapid rise time is applied between the input side and the output side of the photocoupler.

A transistor which causes the reverse breakdown prior to the reverse breakdown of the light-receiving element can be connected in parallel to the light-receiving element.

9 Claims, 4 Drawing Figures

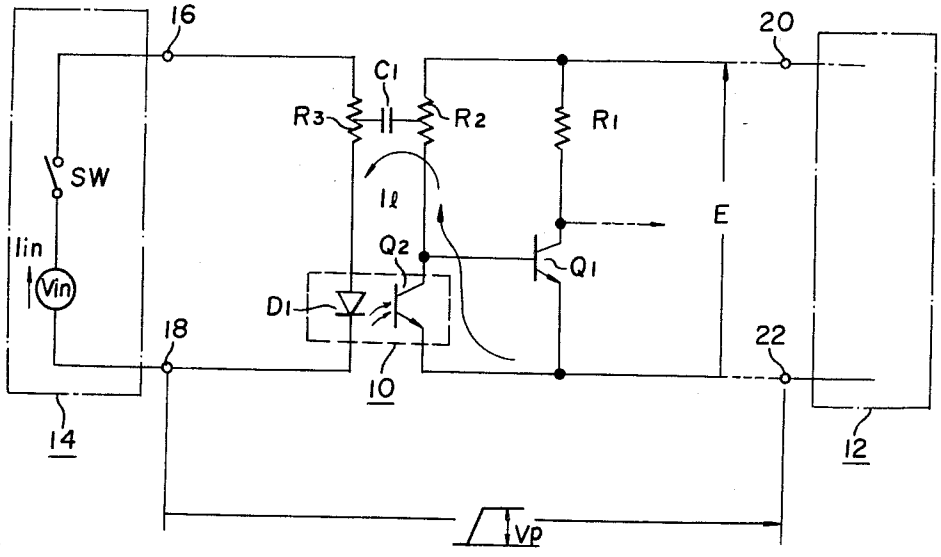


FIG. 1

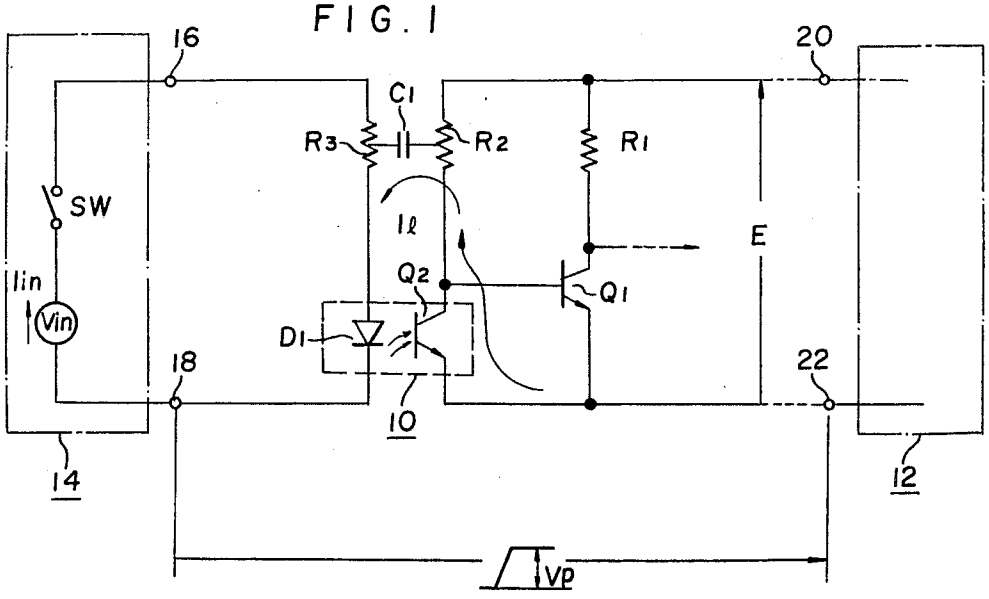
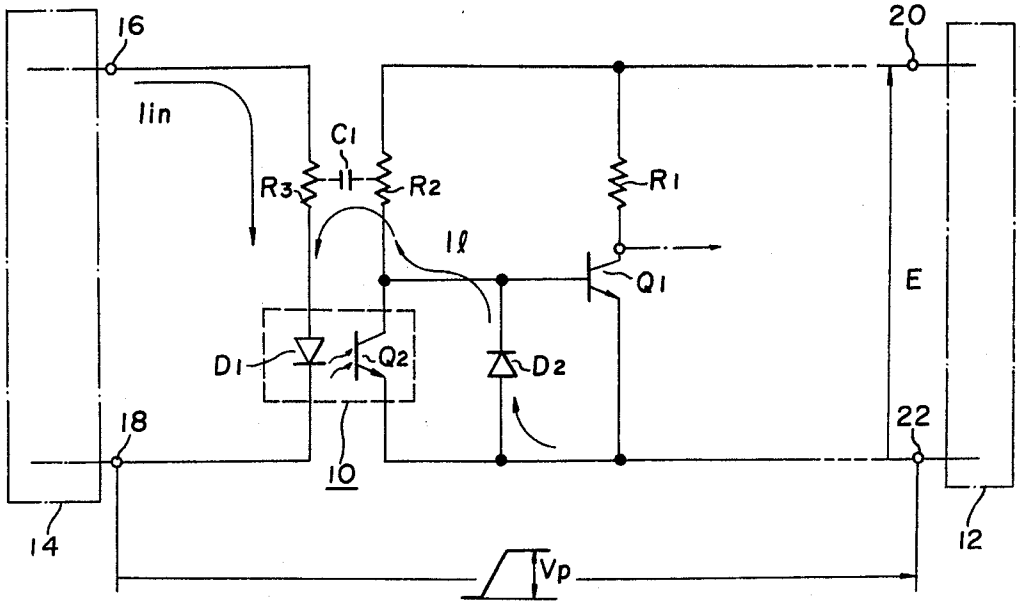

16
20
C1
R3
R2
R1
SW
Il
E
Iin
Q2
Q1
Vin
D1
18
22
10
14
12
Vp

FIG. 2


16
20
Iin
C1
R3
R2
R1
Il
Q1
E
D1
Q2
D2
18
22
10
14
12
Vp

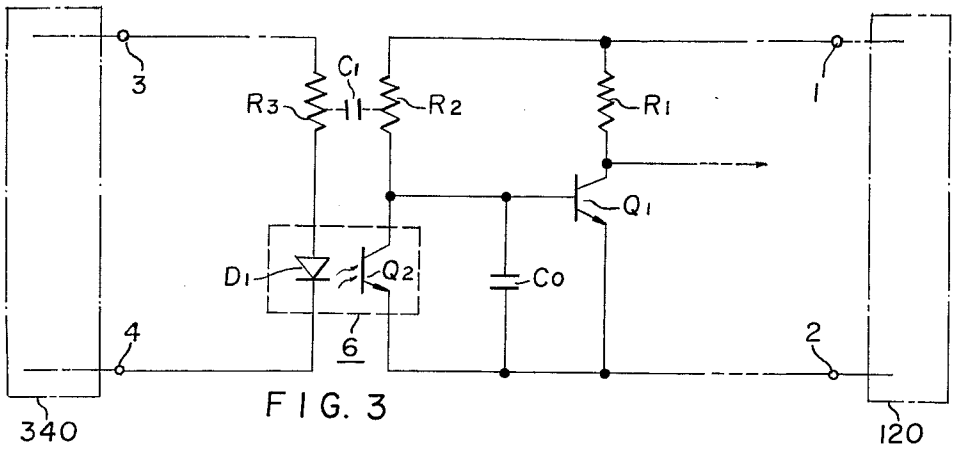
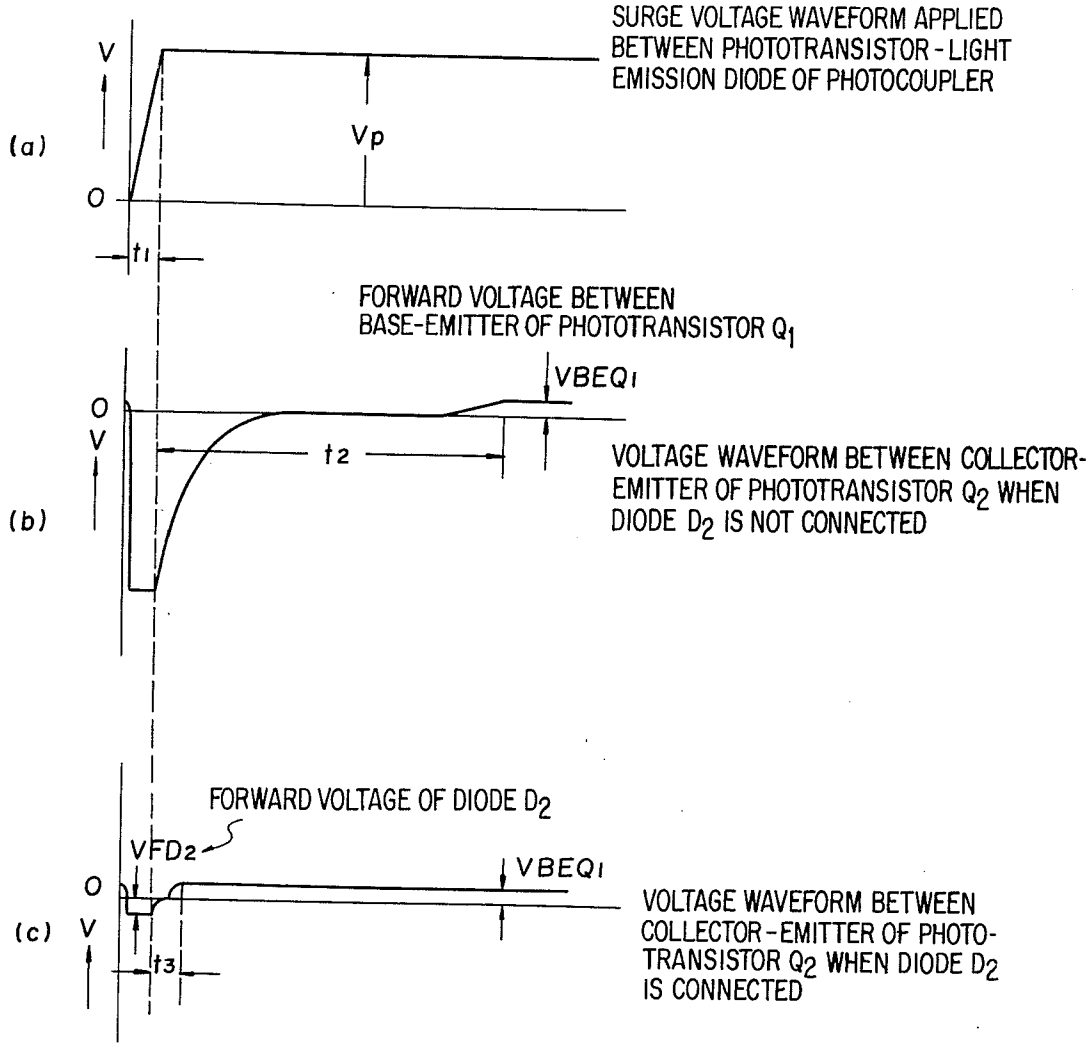

3
C1
R3
R2
R1
1
Q1
D1
Q2
Co
4
6
2
340
120

FIG. 3

FIG. 4


SURGE VOLTAGE WAVEFORM APPLIED BETWEEN PHOTOTRANSISTOR - LIGHT EMISSION DIODE OF PHOTOCOUPLER
(a)
V
Vp
0
t1
FORWARD VOLTAGE BETWEEN BASE-EMITTER OF PHOTOTRANSISTOR Q1
VBEQ1
0
V
t2
(b)
VOLTAGE WAVEFORM BETWEEN COLLECTOR-EMITTER OF PHOTOTRANSISTOR Q2 WHEN DIODE D2 IS NOT CONNECTED
FORWARD VOLTAGE OF DIODE D2
VFD2
VBEQ1
0
(c) V
t3
VOLTAGE WAVEFORM BETWEEN COLLECTOR-EMITTER OF PHOTO-TRANSISTOR Q2 WHEN DIODE D2 IS CONNECTED

COUPLING CIRCUIT USING A PHOTOCOUPLER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an improvement of a coupling circuit using a photocoupler. More particularly, it relates to a coupling circuit having means for preventing erroneous operation caused by a surge voltage etc.

2. Description of the Prior Art

A solid state relay arranged in high density to electrically separate an outer signal source from a circuit for a driving control of a load by coupling with a photocoupler has been well-known in such as U.S. Pat. No. 3,723,769.

Thus, in the solid state relay arranged in high density, the parts of the circuit in the input side are near the parts of the circuit in the output side whereby a stray capacitance is high not to be negligible. When high surge voltage is applied between the input side and the output side, the reverse breakdown of the light-receiving element for the photocoupler is caused to pass a leak current from the circuit in the output side through the stray capacitance to the circuit in the input side. Even though the surge voltage is raised, the light-receiving element is in the ON state whereby the transistor or the other element of the circuit in the output side disadvantageously causes the erroneous operation.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a coupling circuit wherein a light-receiving element does not cause the reverse breakdown even though high surge voltage is applied between the input-output.

Another object of the invention is to prevent the erroneous operation of a coupling circuit wherein means for blocking the reverse breakdown of the light-receiving element of the photocoupler is connected in parallel to the light-receiving element.

The coupling circuit of the present invention is formed with a photocoupler comprising a light emission element whose light emission is controlled by a first circuit and a light-receiving element for driving a second circuit by receiving the light from the light emission element to be turned on, and means for maintaining a voltage between the terminals of the light-receiving element to lower than the reverse breakdown voltage of the light-receiving element.

The coupling circuit of the present invention is also formed with the photocoupler comprising the light emission element whose light emission is controlled by the first circuit and the light-receiving element for driving the second circuit by receiving the light from the light emission element to be turned on, and the switching element connected in parallel to the light-receiving element of the photocoupler to cause the reverse breakdown prior to the reverse breakdown of the light-receiving element.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a connection diagram of the conventional coupling circuit;

FIG. **2** is a connection diagram of one embodiment of the present invention;

FIG. **3** is a connection diagram of the another embodiment of the present invention; and

FIG. **4** shows the operation of the embodiments of the coupling circuits of FIGS. **1** and **2**.

In the drawings, like references designate identical or corresponding parts.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1** and FIG. **4**, the conventional coupling circuit will be illustrated for the easily understandings of the present invention.

The conventional solid state relay has the structure for transmitting the input signal generated from an input signal source V_{in} to a driving circuit **12** by turning on and off a phototransistor Q_2 and a transistor Q_1 which form a photocoupler **10** as shown in FIG. **1**.

The phototransistor Q_2 in the OFF state is turned on by receiving the light from a light emission diode D_1, only when a switch S_w of a driving control circuit **14** is turned on to feed the input signal current I_{in} through a resistor R_3 to the light emission diode D_1. At this time, the base current is fed through a reistor R_2 whereby the transistor Q_1 in the ON state is turned off by forming the short-circuit with the phototransistor Q_2 between the base-emitter by turning on the phototransistor Q_2. Thus, the collector voltage of the transistor Q_1 is raised to apply the output voltage to the driving circuit **12** whereby the driving circuit **12** is operated to drive the load (not shown).

This is the normal operation of the conventional circuit of FIG. **1**. However, in the conventional circuit, even though the switch S_w is in the OFF state wherein the input signal is not transmitted to the next photocoupler **10**, when the surge voltage V_p which has rapid rising time is applied between the terminals **22**, **18** in the polarities of positive at the terminal **22** and negative at the terminal **18** as shown in FIG. **1**, the erroneous operation of the phototransistor Q_2 is caused to be in the ON state for certain time disadvantageously.

The condition and reason of the erroneous operation of the phototransistor Q_2 will be illustrated.

In the circuit prepared for complete electrical separation of the input side from the output side as shown in FIG. **1**, it is necessary to minimize the stray capacitance between the input-output circuits, though the stray capacitance is difficultly prevented. The stray capacitance comprises the capacitance between the input-output of the photocoupler **10** and the stray capacitance in the parts of the circuit in the input side (resistor, diode and wiring) and the parts of the circuit in the output side.

Thus, in general, the capacitance between the input-output of the photocoupler **10** which is commercially available is remarkably small as about 0.2 PF, which is negligible. Accordingly, the stray capacitance is mostly the stray capacitance of the parts of the circuits for the input and output.

Recently, it has found the tendency to arrange parts in high density for miniaturization for all of the circuits. In these circuits, the parts of the circuit in the input side are near those of the output side whereby the stray capacitance increases to be difficultly omitted and to be about 2 PF which is not negligible. In FIG. **1**, the stray capacitance is designated as C_1.

When the circuit of FIG. **1** is used in the interface between the 200 Volt power source and the IC driving circuit, it is estimated to be more than 1000 V/μs of the voltage rising coefficient in the rise time of the surge voltage V_p between the input-output.

Referring to FIG. 1 and FIG. 4, the phenomenon caused by applying the surge voltage V_p to the stray capacitance between the input-output, will be illustrated.

When the surge voltage V_p (FIG. 4*a*) which has the rapid rise time is applied between the terminals **22, 18** of the circuit of FIG. **1**, the closed circuit is formed with the stray capacitance C_1 whereby the surge voltage V_p applied to the terminals **22, 18** is applied under division, through the stray capacitance C_1 between the collector and emitter of the phototransistor Q_2. Accordingly, the reverse breakdown of the junction between the base-emitter of the phototransistor Q_2 is resulted to pass the leak current I_l through the path of FIG. **1**.

When the reverse breakdown of the junction of the base-emitter of the phototransistor Q_2 is resulted, the carriers are accumulated in the base of the phototransistor Q_2 whereby the surge voltage V_p applied between the terminals **22, 18** is raised to prevent the passage of the leak current I_l. When the voltage E for the terminals **20, 22** begins to be applied between the collector-emitter of the phototransistor Q_2, the phototransistor Q_2 is turned on whereby the collector voltage of the phototransistor is not raised. When the carriers in the base of the phototransistor Q_2 are completely lost to recover the OFF state of the phototransistor Q_2, the collector voltage of the phototransistor Q_2 is raised.

It is to be a long turn-off time t_2 to reach the collector voltage of the phototransistor Q_2 to the forward voltage V_{BEQ_1} for the base-emitter junction of the phototransistor Q_1 by turning the phototransistor Q_2 from the ON state to the OFF state. Accordingly, the transistor Q_1 is in the ON state during the turn-off time, the base current is turned off because of the blocking of the base current disadvantageously.

The voltage waveform between the collector-emitter of the phototransistor Q_2 during the above-mentioned stages is shown in FIG. 4*b*.

On the other hand, when the surge voltage V_p having opposite polarity is applied, that is to apply the surge voltage V_p in the polarities of positive at the terminal **18** and negative at the terminal **22**, the surge voltage V_p is applied under division through the stray capacitance C_1 to the phototransistor Q_2 at positive polarity in the collector side. In this case, the phototransistor Q_2 is short-circuited at the base-emitter junction of the transistor Q_1 whereby the breakdown of the phototransistor Q_2 is not caused.

As stated above, in the coupling circuit for coupling the input signal source which is electrically separated (first circuit) through the photocoupler to the other circuit (second circuit), it is serious disadvantage to erroneously operate by the surge voltage applied between the first and second circuits.

The present invention is to provide the improved coupling circuit which has not the above-mentioned disadvantages.

FIG. **2** is a connection diagram of one embodiment of the coupling circuit of the present invention.

In FIG. **2**, the reference numeral **10** designates a photocoupler comprising the light emission diode D_1 and the phototransistor Q_2. The anode of the light emission diode D_1 is connected through the resistor R_3 to the terminal **16** and the cathode of the light emission diode D_1 is connected to the terminal **18**. The driving control circuit **14** for controlling the light emission of the light emission diode D_1 is connected between the terminals **16, 18**. The collector of the phototransistor Q_2 is connected through the resistor R_2 to the terminal **20**, and the emitter is connected to the terminal **22**. The diode D_2 is connected in parallel between the collector-emitter of the phototransistor Q_2 in the reverse direction. The base and the emitter of the transistor Q_1 are respectively connected. The collector of the transistor Q_1 is connected through the resistor R_1 to the terminal **20**. The driving circuit **12** for applying the voltage E between the terminals **20, 22** and driving the load (not shown) by the collector output voltage of the transistor Q_1, is connected between the terminals **20, 22**.

In the structure, when the input signal current I_{in} is fed from the driving control circuit **14** through the resistor R_3 to the light emission diode D_1, the light emission diode D_1 emits the light whereby the phototransistor Q_2 in the OFF state is turned on by receiving the light of the light emission diode D_1. During the time, the base current is fed through the resistor R_2 whereby the transistor Q_1 in the ON state is turned off by forming the short-circuit between the base-emitter by turning on the phototransistor Q_2. The collector voltage of the transistor Q_1 is raised and the output voltage is applied to the driving circuit **12** to actuate the driving circuit **12** to drive the load. At the time, the voltage applied to the diode D_2 is less than the reverse blocking voltage of the diode; whereby the normal operation of the diode is given without the reverse breakdown in the circuit of FIG. **2**.

On the other hand, when the surge voltage V_p is applied between the terminals **22, 18**, the closed circuit is formed through the stray capacitance C_1 as the conventional circuit of FIG. **1**, whereby the surge voltage V_p applied between the terminals **22, 18** is applied through the stray capacitance C_1 between the collector-emitter of the phototransistor Q_2.

In the conventional circuit of FIG. **1**, the reverse breakdown of the junction between the emitter-base of the phototransistor Q_2 is caused by the voltage. In the circuit of FIG. **2**, the diode D_2 is connected whereby the leak current I_l passed through the stray capacitance C_1 is by-passed to only the diode D_2 to fix the voltage between the collector-emitter of the phototransistor Q_2 by the forward voltage V_{FD_2} of the diode D_2 whereby the reverse breakdown of the emitter-base junction of the phototransistor Q_2 is prevented. When the surge voltage V_p applied between the terminals **22, 18** is raised to prevent the leak current I_l after this time, the diode D_2 has the accumulated carriers to prevent the immediate recovery of the reverse blocking function of the diode D_2 and the transistor Q_1 tends to turn to the OFF state. However, the transistor Q_1 is not turned to the OFF state because the reverse recovering time of the diode D_2 is short as about 0.5 μs which is enough shorter than the switching speed of the transistor Q_1.

The voltage waveform at the both ends of the diode D_2 is shown in FIG. 4*c*. As it is clear from the waveform of FIG. 4*c*, even though the diode D_2 is connected, the base current of the transistor Q_1 is blocked during the time $t_1 + t_3$ of the sum of the rise time t_1 of the surge voltage V_p and the reverse recovering time t_3 of the diode D_2 (the diode D_2 is turned to the OFF state to reach the terminal voltage of the diode D_2 to the forward voltage V_{BEQ_1} of the base-emitter junction of the transistor Q_1). As stated above, the time t_3 is about 0.5 μs which fur shorter than the turn-off time of the transistor Q_1 (100 μs). Accordingly, the transistor Q_1 is not turned to the OFF state whereby the normal operation is maintained.

As stated above, the erroneous operation of the conventional circuit can be completely prevented as shown in FIG. 1 by connecting the diode D_2 in parallel between the collector-emitter of the phototransistor Q_2 in the reverse direction.

The erroneous operation preventing function of the excellent circuit can be attained with one diode.

FIG. 3 is a connection diagram of the another embodiment of the coupling circuit of the invention. In the embodiment, the diode D_2 in FIG. 2 is substituted for with a capacitor C_o. The capacitor C_o is selected to have a large capacitance such as 1000 PF which is quite larger than the stray capacitance C_1.

In the structure, the leak current I_l is passed through only the capacitor C_o to fix the voltage between the collector-emitter of the phototransistor Q_2 to less than the reverse breakdown voltage of the phototransistor Q_2. Accordingly, the reverse breakdown of the phototransistor Q_2 is blocked to prevent the erroneous operation.

In the above-mentioned embodiments, the diode or the capacitor is used as the element connected in parallel to the phototransistor Q_2. The same effect can be attained by using a Zener diode.

It is also possible to attain the same effect without using the diode, the capacitor or the Zener diode by using the transistor Q_1 which has a low reverse breakdown voltage of the base-emitter junction (as the next one of the phototransistor Q_2) whereby the reverse breakdown of the junction of the transistor Q_1 is resulted prior to the reverse breakdown of the junction of the phototransistor Q_2.

In the embodiments, the photocoupler of the phototransistor is used as a light-receiving element. Thus, the same effect can be attained when a photocoupler of a photothyristor is used as the light-receiving element.

As stated above, in the coupling circuit of the present invention, the means for blocking the reverse breakdown of the light-receiving element of the photocoupler is connected in parallel to the light-receiving element thereby attaining the coupling circuit which does not cause the erroneous operation by applying high surge voltage between the input-output.

What is claimed is:

1. A coupling circuit for connecting a first circuit and a second circuit comprising:

a photocoupler including a light emission element whose light emission is controlled by the first circuit and a light receiving element for driving the second circuit by receiving the light from the light emission element to be turned on;

the light emission element and the light receiving element being electrically connected through a stray capacitance arising between the first circuit and the second circuit so that a reverse breakdown of the light receiving element can be produced by a surge voltage applied through the stray capacitance to the light receiving element; and

means connected in parallel to the light receiving element for blocking the reverse breakdown of the light receiving element.

2. A coupling circuit according to claim 1, wherein said means for blocking the reverse breakdown of the light-receiving element is means for maintaining the voltage between the terminals of said light-receiving element lower than the reverse breakdown voltage of said light-receiving element.

3. A coupling circuit according to claim 2, wherein said means for maintaining the voltage is a diode.

4. A coupling circuit according to claim 2, wherein said means for maintaining the voltage is a capacitor.

5. A coupling circuit according to claim 2, wherein said means for maintaining the voltage is a Zener diode.

6. A coupling circuit according to claim 1, wherein said means for blocking the reverse breakdown of said light-receiving element is a switching element which has a reverse breakdown prior to the reverse breakdown of said light-receiving element.

7. A coupling circuit according to claim 6, wherein said switching element is a transistor.

8. A coupling circuit according to claim 1, wherein said light emission element is a light emission diode and said light-receiving element is a phototransistor.

9. A coupling circuit according to claim 1, wherein said light emission element is a light emission diode and said light-receiving element is a photothyristor.

* * * * *